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PROBLEMS AND RECENT IMPROVEMENTS IN THE PREPARATION
AND USE OF GRASS SILAGE

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In 1952 it was estimated that the Nation's hay crop came from 75 million acres from which over 100 million tons of hay per year was produced worth about 2.6 billion dollars. During the past five-year period, increasing amounts of the Nation's hay crop has been harvested as grass silage. During the period 1946-50, 4% of the dairy farmers supplying crop information to the U.S.D.A. reported making grass silage. In 1953 the number increased to 21%. This shift is due to the desire, of the farmer to overcome the weather hazards of hay making, especially in the semi-humid areas, and to the development of farm machinery for more rapid and efficient handling of silage.

Effectiveness of Various Methods of Harvesting

Extensive experiments were conducted at Beltsville on various methods of harvesting alfalfa as a feed for dairy cattle. The results collected over a five-year period on the field losses, storage losses, and percentages preserved for feeding are shown in Table 1. These results showed that large losses of dry matter were incurred when the alfalfa crop is rain damaged. These losses are due to leaching and to leaf shatter in turning the hay in the windrow with a side delivery rake to aid in getting the crop sufficiently dry to store. The resulting hay was of poor quality and low in feeding value. The practical farmer knows that the entire crop can be lost where excessive rainfall occurs.

Table 1. Percent of alfalfa dry matter in field losses, storage losses, and preserved for feeding when harvested by various methods

	Field losses %	Storage losses %	Preserved for feeding %
Field cured hay - rain damaged	32.6	4.0	63.4
Field cured hay - no rain damage	17.4	3.6	79.0
Barn dried hay - no heat	12.6	6.4	81.0
Barn dried hay - heat	13.4	1.8	84.8
Wilted silage	5.8	11.0	83.2
Dehydrated hay	5.6	4.1	90.3

From USDA Tech. Bul. 1079.

The results also showed that barn drying or making the crop into wilted silage was the most efficient in terms of costs and of feed dry matter preserved. With these results as a background, further experiments were initiated into methods of preserving hay crops as grass silage.

Present Knowledge of Silage Making

Despite the importance of silage making in our agricultural economy, the research effort going into the problems associated with silage making is indeed small compared to other agricultural problems. Much of the research effort in the past has been exerted through the use of trial and error technics. The wilting method was developed at Beltsville using this technic but did not result in producing information into the fundamental processes involved.

Studies using the technics of chemistry, bacteriology, agricultural engineering, agronomy, and plant physiology have not been utilized in a team attack on the problems of silage making. Though the processes are somewhat similar, it has been said that we know more about the scientific principles of producing sauerkraut than we know about making grass silage.

Briefly, according to our present knowledge, we know that silage is made primarily by means of the fermentation of the carbohydrates in the plant material with the resulting production of certain organic acids such as butyric, lactic, formic and acetic acids. The organic acids increase the acidity of the silage which aids in its preservation. We know that exclusion of oxygen from the silage mass is important in the fermentation process. This important principle is sometimes not fully appreciated by the practical farmer. We know that silage can be made in different structures with differing success and varying losses. We know that the proper use of the wilting procedure or the use of different types of preservatives will usually produce a good silage. We have some knowledge of the feeding value of the grass silages.

With the development of modern machinery, new types of structures for storage and new preservatives, the scientist in my experience does not have the answers for those seeking information of the effects of these new developments on the silage making process because of the primary lack of fundamental information.

The Water Problem

Prior to the development of the direct-cut field forage chopper, a great deal of the grass silage was made by means of the wilting procedure.

The wilting procedure consists of cutting the crop with a mower, permitting the crop to wilt from one to five hours until the moisture content is between 60 and 70%, raking with a side delivery rake, chopping from the windrow into wagons or picking the crop up with a hayloader on to trucks, chopping and blowing into the silo. On the other hand, the direct-cut forage chopper cuts, chops and blows the crop directly into trucks or forage wagons and thus does not permit the wilting of the crop in the field. This introduces a new set of problems. The water problem as a result of the use of the direct-cut chopper is illustrated in Table 2.

Table 2. The water problem in high moisture silage in a tower silo

100 tons wilted crop	175 tons fresh green crop
<u>65% moisture</u>	<u>80% moisture</u>
65 tons water	140 tons water
35 tons DM as silage	35 tons DM as silage
Difference 75 tons water	
12% fermentation loss	15% fermentation loss
<u>3% field loss</u>	<u>13% seepage loss</u>
15% total loss	28% total loss

Difference 13% of DM or 4.5 tons DM
or 5.3 tons of hay equiv.

To bring 80% moisture crop to 70% moisture would require 20 tons of beet pulp or about 230 lbs. beet pulp per ton equal to 36% of the DM in the silo.

It can be seen from the above Table 2 that the farmer must handle 75 more tons of water if his crop contains 80% moisture compared to the wilted crop containing 65% moisture in order to store a total of 35 tons of dry matter. This dry matter fraction excludes moisture and contains all of the nutrients obtained from the crop.

Besides the extra power required to handle the 75 tons of water, it also creates a seepage problem. When the crop contains 80% moisture, one might expect that as much as 50 tons of water will seep from the tower silo carrying with it valuable nutrients since the seepage contains 7 to 8% dry matter. In experiments at Beltsville, the total DM loss from the stored dry matter from a high moisture crop will be between 8 and 15% in the form of seepage. The effect of the moisture content of the crop on seepage dry matter losses is shown in Table 3.

Table 3. Estimated seepage dry matter losses from tower silos

80% moisture	8-15%
75% moisture	5-8%
70% moisture	1-2%
65% moisture	1%

Considering the information in Table 2, comparing the losses in making wilted silage and wet silage, there can be as much as 13% difference in loss of DM from these two theoretical silages or a difference of 4.5 tons of DM from the original 35 tons of DM.

The seepage loss according to preliminary data at Beltsville will be about halved if the silage is stored in the horizontal type of silo such as the bunker silo. Further data are needed on this point. Likewise, we need further data on the effect of type of crop, depth of storage and length of cut on seepage losses.

The addition of a feedstuff which has the ability to take up water has been helpful. However, as shown in Table 2, it would require about 230 lbs. of beet pulp per ton of wet silage to bring the moisture equivalent from 80% to 70%. Such addition of beet pulp would result in the silage dry matter containing 36% of beet pulp as it is stored. This raises the question whether the farmer has the silo for the purpose of storing beet pulp or forage.

In laboratory studies at Beltsville, the water holding capacity of several feedstuffs was studied as shown in Table 4. Citrus pulp, beet pulp and ground hay were best, dried distillers grains intermediate while ground cereal grains were poorest. The use of chemical preservatives does not reduce the seepage problem.

Table 4. Water uptake of 30 grams of feedstuffs following 5.0 lbs. pressure/sq. in.

	<u>Water (grams)</u>
Beet pulp	97
Beet pulp (ground)	91
Citrus pulp	63
Citrus pulp (ground)	63
Brewers' grain	46
Corn cobs	44
Corn cobs (ground)	64
Bran	10
Corn meal	9
Chopped hay	63
Ground hay	50

The Use of Preservatives in Making Grass Silage

Many different materials have been used to aid in the preservation of silage. These materials naturally divide themselves into two classes, namely; feedstuffs and chemical preservatives. Among the feedstuffs are such materials as molasses, ground grains, beet pulp and citrus pulp. These feedstuffs add nutrients to the silage with an attendant fermentation loss of about 15%. The chemical preservatives have consisted of sulfur dioxide, sodium metabisulfite and a commercial preservative containing calcium formate and sodium nitrite.

Since the development of the direct-cut forage chopper and the necessity for the preservation of high moisture crops, the use of preservatives has increased. Their effectiveness can vary from crop to crop and year to year. For instance, in research at Beltsville it was shown that a chemical preservative was of value one year but of no value the following year with a similar crop. The effectiveness of the preservative was dependent upon the quality of the silage in the untreated control. A summary of the data is shown in Table 5.

Table 5. Effect of using silage preservative in two different years in tower silos.

	1953		1954	
	Untreated	Kylage	Untreated	Kylage
AS STORED				
Dry matter - %	19.4	20.6	18.4	18.3
Crude protein - %	18.0	17.2	16.7	16.8
Crude fiber - %	26.0	25.5	22.8	23.4
Sugar - %	5.4	5.6	8.8	9.1
AS REMOVED				
pH	4.98	4.52	3.76	3.67
Amon. nitrogen ¹ - %	24.5	14.1	7.5	6.3
Acetic acid - %	3.25	3.05	1.98	1.51
Butyric - %	3.05	1.05	0.03	0.03
Lactic acid - %	1.80	4.90	7.78	8.00
DM preserved - %	74.4	77.0	76.4	76.8
Sil.DM consumed/cow/ day - lbs.	15.2	17.8	22.0	21.5

¹As percent of total nitrogen.

Adapted from ARS 52-9.

It will be noted that in 1953 the use of preservative resulted in a silage lower in ammonia nitrogen, lower in butyric acid, higher in lactic acid, and with slightly more dry matter preserved than in the corresponding control silage. The following year, 1954, there were no differences between the untreated and treated silage because the untreated silage was also good silage. The presence of butyric acid is evidence of excessive fermentation losses.

Because, at this time, we have no way of predicting the quality of silage which will result from no preservation treatment, we have been recommending their use with high moisture crops. A preservative should be no excuse for using poor ensiling methods. A preservative is not necessary and probably should not be used with wilted crops.

The Use of Plastic Covers on Bunker Silos

The development of plastic sheets or covers will be largely responsible for the continued use of horizontal storage. The plastic cover prevents water from rain or snow from penetrating the silage mass and permits the exclusion of air from the large surface of horizontal silos. The usually large loss of 30 to 40% or more of the dry matter attendant with poor packing or heavy rainfall in the uncovered horizontal silo can be reduced to 15%. This loss is primarily due to fermentation and seepage with little or no surface spoilage.

The relative effectiveness of the use of covers applied in various ways is shown in Table 6. It is evident that the cover must be weighted with a material, like sawdust, over the entire surface. Weighting at the edges is not sufficient because air entering in one or two holes will expose the entire surface of the silage. The weighting material tends to confine the loss from a hole or puncture to a small area. The spoilage per square foot is a minimal figure for this loss since gaseous losses such as carbon dioxide are not accounted for in the spoilage. The data show that in 1954, the spoilage loss amounted to 6-7 lbs. of dry matter per square foot whereas by proper application of the cover the loss was reduced to 0.2 to 0.5 lbs. per square foot. If forage dry matter were assigned a value of 1 1/2 cents per pound (equivalent to 15% moisture hay at \$25.50 per ton) the plastic cover would be worth 10 1/2 cents per square foot, plus the unknown value of gaseous loss, plus the value of reduced leaching by rain, plus the value of decreased labor of removal of spoilage. Thin plastic covers applied from 6-20 foot wide rolls can be obtained for 2 to 3 cents per square foot and replaced each year. It is believed that the same information would apply to trench silos.

The farmer who believes that he has very little loss where no cover is used or where the silage is covered with lime or similar materials is only fooling himself, especially in areas where there is considerable rainfall. He does not realize the extent of loss due to carbon dioxide

Table 6. Losses and recovery of silage dry matter stored as affected by covers

Silo	Dry Matter		Dry Matter Lost		Dry Matter Preserved %	Spoilage / Sq. Ft. Dry Matter Lbs.
	%	Seepage %	Fermentation %	Spoilage %		
<u>1954 Hay Crop in Bunkers - 8 Mil. Vinyl, Taped Seams, Not Weighted</u>						
1 Long	29.1	1.1	15.9	11.9	71.1	6.1
2 Chopped	28.7	0.6	18.4	12.3	68.7	7.3
<u>1955 Hay Crop in Bunkers - Sisal Kraft Paper Followed by Weighted Neoprene-Nylon Sheets</u>						
1 Long	22.0	2.5	22.2	4.2	71.1	2.0
2 Chopped	21.8	3.3	20.9	3.2	72.6	1.9
<u>1956 Hay Crop in Bunkers - Weighted Neoprene-Nylon Sheets</u>						
1 Chopped M.B.	21.5	3.8	10.5	0.5	85.2	0.2
2 Chopped	20.5	2.4	6.8	1.3	89.5	0.5
<u>1956 Hay Crop - Straight Sided Stack on Ground - 4 Mil. Polyethylene + Soil</u>						
	21.3	-----16.0-----		4.9	79.1	0.8
<u>1955 Pilot Stacks Built on the Ground</u>						
Polyethylene	21.7	-	-	-	-	0.9
Vinyl	22.9	-	-	-	-	0

escaping into the air from fermentation, or the amount of silage dry matter loss represented by two or three inches of black top spoilage.

If trench and bunker silos continue to be used, and there is reason to believe that they will be, properly weighted plastic covers will increase in use. In areas where there is considerable rainfall they are essential.

Types of Silos

The tower silo has been the conventional type of structure used for storage of grass silage for many years. The gas-tight silo with the bottom unloader is an unique modification of the tower silo. However, during recent years, silos of the horizontal type such as trench and bunker types have come into prominence. The lower initial cost, and the possibilities of mechanized filling and feeding, or self-feeding of the silage has attracted many farmers to the use of trench or bunker silos. Stacks have also been used for emergency or temporary storage of silage.

The effectiveness of the various structures in preservation of dry matter of grass silage is dependent to a considerable extent upon the technics and management of the crop by the farmer at the time of ensiling. More care is necessary in making silage in the horizontal type silo than in the tower silo because of the lack of weight from the depth of silage as well as the greater surface area exposed. Because of these two factors more difficulty is experienced in the exclusion air from the silage mass. These two difficulties can be partially overcome by packing the silage with a tractor during the filling process and by covering the surface of the silage with plastic covers held in place with some such material as sawdust.

One year's results on the comparative effectiveness of tower and bunker storage of silage is given in Table 7. These data show that the seepage loss (3.8%) was less for the bunker silo than for similar silage stored in a tower silo (8.4%). This difference was largely responsible for more dry matter being preserved in the bunker silo (85.2%) than for similar silage stored in the tower silo (77.9). Where the crop was wilted, the figure was 86.3%.

These preliminary results indicate that for a wet crop, silage dry matter can be as well or better preserved in a bunker silo as in a tower silo. However, it should be pointed out that special care was taken with the bunker silo to be certain of adequate packing and covering the crop in the silo. It should be pointed out from the farmer's standpoint that unless adequate precautions are taken, the loss can range from 40 to 100%.

Table 7. Comparative efficiency of tower and bunker silos

	Wilted Tower Silo	Not Wilted Metabisulfite Tower Silo	Not Wilted Metabisulfite Bunker Silo
AS STORED			
DM - %	30.0	22.2	21.8
Protein - %	12.8	13.6	13.4
Fiber - %	25.9	24.9	24.9
Sugar - %	8.6	8.6	8.4
AS REMOVED			
DM - %	29.1	25.4	22.4
pH	4.20	4.22	4.36
Amon. N. ¹ - %	12.5	10.1	9.7
Acetic acid - %	1.9	1.2	1.5
Butyric acid - %	2.1	0.38	0.49
Lactic acid - %	5.2	4.2	3.8
Seepage loss DM - %	1.7	8.4	3.8
Fermentation loss DM - %	12.0	13.7	10.5
DM preserved - %	86.3	77.9	85.2
DM consumed/cow/day - lbs.	23.3	20.5	20.1
FCM produced - lbs.	24.5	23.5	25.1

¹As percent of total N.

We have not recommended the storing of wilted silage in trench or bunker silos because of the difficulty of packing and excluding air. With the development of plastic covers to exclude air, the storage of wilted silage in these structures should be investigated because of the better acceptability of wilted silage by cattle.

It seems likely that horizontal storage of silage crops will continue to increase providing the importance of packing and covering the silage stored in these structures is fully understood by the farmer. The advantages of lower initial cost per ton of silage stored, and possibilities of mechanization in harvesting and feeding the silage will encourage farmers to use the method. The bunker or trench silo will be primarily used.

The question of the use of such structures in warm climates remains to be answered. The exposed silage removal surfaces may permit excessive losses. Perhaps these losses may be quite high in the summer months.

Table 8. Relation between the moisture content of silage and the amount of silage dry matter consumed by non-lactating dairy cows¹

Crop harvested	Moisture content of silage	Dry matter eaten per 100 lbs. of live weight per day
	Percent	Pounds
Orchard grass:		
First cutting (boot stage):		
Fresh green-----	79.7	1.36
Wilted-----	66.9	2.00
Second cutting (early hay stage):		
Fresh green-----	71.8	2.08
Fresh green + 5% dry grain-----	69.7	2.21
Wilted-----	59.5	2.11
Alfalfa:		
First cutting (1/10 to 1/4 bloom):		
Fresh green-----	77.9	1.23
Wilted-----	72.7	1.94
Wilted-----	65.6	2.34
Half-dry ² -----	45.7	2.52
Soybeans:		
First pods forming (dry season):		
Fresh green-----	74.1	1.52
Fresh green + 10% dry grain-----	69.9	2.19
Wilted-----	58.1	1.85

¹From Beltsville experiments in 1950-52.

²In gas-tight silo; no mold.

From BDInf. 149

Table 9. Average gain in body weight of dairy heifers from 12 to 24 months of age

	Weight at 12 months (lb.)	Weight at 24 months (lb.)	Gain (lb.)
Jersey			
Group 1 Alf. Hay	417	737	320
Group 2 Alf. Hay & Alf. Sil.	360	703	343
Group 3 Alf. Sil.	338	646	308
Holstein			
Group 1 Alf. Hay	670	1151	481
Group 2 Alf. Hay & Alf. Sil.	554	1039	485
Group 3 Alf. Sil.	486	911	426

Jour. Dairy Sci. 38: 1246 (1955).

The development of the top unloader, coupled with the possibility of mechanical feeding will make the tower silo more attractive for storage of forage in the future.

The Acceptability of Grass Silage by Cattle

Another problem on which we need further information concerns the acceptability of grass silage by cattle. Information at Beltsville shows that where silage is the principal or sole forage being fed, the higher the moisture content of the silage the less total dry matter cattle will consume. This effect is shown in Table 8.

It is true that more pounds of wet silage will be consumed than of the dry type of silage, but because of the high moisture content of the wet silage less total pounds of dry matter are actually eaten.

Data at Beltsville also show that dairy heifers will consume more total dry matter from alfalfa hay than from wilted silage which results in more total digestible nutrients being consumed and greater growth compared to silage-fed heifers. This effect is shown in Table 9.

The decreased acceptability for silage is not due to water per se since the consumption of the dry matter is not increased by feeding dried silage. The addition of silage seepage to hay causes a decrease in dry matter consumption. Whether the decreased consumption of silage is due to decreased palatability or to decreased appetite because of some metabolic disturbance in the animal is not clear at this time. It is important that the cause of this effect be determined and work is now proceeding in this direction.

Where grain is fed at moderate levels, such as to a milking herd, the importance of the dry matter content of the silage to consumption is not entirely clear at this time. It appears from feeding trials where grass silage is fed, slightly less dry matter may be consumed as silage than hay, and milk production is not affected. Further information is needed to clear up this point.

Fundamental Studies at Beltsville

In experiments at Beltsville, three cuttings of alfalfa and three cuttings of orchard grass were harvested and placed in small one-ton capacity steel silos. Each cutting and crop was treated in five different ways in five different silos to exclude or include air in varying degrees. In one set of silos, air was pumped into the silos for eight hours after filling. A total of 30 silos were involved.

The results showed that the alfalfa, as judged by chemical quality characteristics, was more resistant to the insult of air inclusion than the orchard grass. Likewise, the second crop was less resistant to the insult of air inclusion than the first crop for both the alfalfa and orchard grass. The third crop was intermediate. The results also showed that the type and quality of silage is determined in the first 24 to 48 hours.

These results indicate that crops and cuttings differ in their resistance to insult by air inclusion and their ability to make good silage. Why did these differences exist? We cannot entirely explain the differences with our present state of information, but research is in progress in an attempt to determine the cause of the differences.

The results further showed that the exclusion of air during the fermentation process and during the storage period of the silage in the silo is one of the most important factors the farmer should keep in mind. Any method or technic which will aid in air exclusion should be carefully practiced. Such factors as fine chopping, a tight silo with tight doors, and a proper top seal are important in the tower silo. In the bunker or trench silo, the silage should be continuously packed with a tractor and the surface sealed with some form of weighted plastic cover.

Practical Implications

It is my belief that the making of hay crops into silage in the semi-humid areas for winter feeding will be with us for a long time. In areas where good quality hay can be made without weather damage, silage making will probably not increase. In the South, we have heard considerable about year round pasture for the livestock herds. From my observations and those of others, this may not be an attainable goal and we should accept the fact that we will have to grow forage in a favorable season and store it in the form of silage for use during the unfavorable part of the growing season.

The use of silage in the forage program has been, and is being, challenged in some quarters because of the problems previously mentioned. It must be admitted that grass silage has certain limitations which must be recognized. However, we should recognize the limitations and fit its use into the forage program and thus still make use of its advantages.

At Beltsville, we have always recommended the feeding of some hay where grass silage is fed in order to maintain a high level of dry matter consumption. This system fits in with the practice of making

the first crop of grass or legume forage into silage and, if possible, making the second or third crop into hay either by field curing or barn drying. This practice also fits into the weather pattern in most areas. We have recommended about 5 lbs. of hay for a 1,000 lb. cow where wilted silage is fed. Where a direct-cut high moisture silage is fed as much as 10 to 15 lbs. of hay should be fed or whatever the animal will consume. Of course, in any feeding situation the farmer should watch the condition of the cow and the rate of decline in milk production. If the decline exceeds 8 to 10% per month, the rate of grain feeding may need to be increased.

It is my belief that there will be a return to the practice of wilting the high moisture crops before ensiling in tower silos. We are not in position at this time to recommend wilting for storage of the crop in trench or bunker silos. The advantages of direct chopping from a labor and machinery standpoint are not as great as originally thought. The disadvantages of seepage losses, poor quality silage, and poor acceptability by cattle of high moisture silage are difficult to overcome. Where good quality hay can be made without weather damage, it is the preferred feed. However, weather damaged poor quality hay is not a preferred feed.

The livestock industry is dependent upon forage as an economic source of nutrients and it is important that those of us interested in agriculture to develop further economical methods for supplying that forage when it is needed so that it is acceptable to the animal and economical to use.

